

# **REMEDIATION OF STORMWATER RESIDUALS DECANT WITH HYDROCOTYLE RANUNCULOIDES**

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## **Abstract**

A stormwater residuals decant treatment regime employing floating marsh pennywort, *Hydrocotyle ranunculoides*, is apparently effective at remediating lead-contaminated suspended solids, 25 microns and less, after one year's experience in Portland, Oregon.

Gravity settling provided by Portland's existing stormwater sediment dewatering facility does not give sufficient pollutant removal, and Portland experienced occasional exceedances of local pretreatment limits for lead. In March of 2001, Portland began a full-scale trial of stormwater residuals decant treatment using marsh pennywort, or *Hydrocotyle ranunculoides*. This free-floating aquatic plant is locally acceptable for aquatic landscaping and needs no special control.

First-year review found this project apparently successful and very inexpensive. Preliminary second-year data continues to show promise and minimal cost.

## **Project Context**

Portland, Oregon maintains a separate stormwater collection and treatment system, which includes over 15,000 sumps and sedimentation manholes that drain only curbed and guttered urban streets. Over 1,800 metric tons of stormwater residuals are recovered by vacuum eductor truck (Vactor<sup>®</sup>) from these facilities annually. These residuals are contaminated with common urban stormwater pollutants, most prominently TPH, lead and cPAHs. The contaminants are mostly fixed -- adsorbed to the fine soils which dominate these residuals (Bretsch, 2002). On average, fine particles 31.2 microns and less account for 22% of residual solids particle counts.

The residuals are recovered along with substantial amounts of standing stormwater and injected chlorinated tap water. They are discharged onto sloped pads at the City's Inverness Stormwater Sediment Dewatering Facility from vacuum eductor trucks at about 90% water by weight, or pea soup consistency. After dewatering to about 25% water by weight, or dry enough to pass a "paint filter test," the material is removed for thermal remediation and recycling.

Decant off Portland's tennis court size Vactor<sup>®</sup> dumping pads flows through sloped channels with weirs of wood and screen fabric intended to catch the large floatables, then through a system of ductile iron pipe and shallow below-ground sedimentation manholes to a two-celled settling tank made from a section of the old aeration settling basin of an abandoned wastewater treatment plant. An overflow stand pipe in the second cell allows continuous discharge to the City's sanitary sewer system.

This dewatering process yields about 684,000 liters of decant annually. The decant is pretreated prior to discharge into the City's sanitary sewer system in order to protect the City's wastewater system biosolids quality, a critical City objective.

The decant carries ultra-fine suspended solids which are negatively charged and resistant to settling by gravity (Collins, 1999; Ghezzi, M., Collins, J., Moore, J., Bretsch, K., and Hunt, L., 2001). A \$300,000 facility improvement provided additional gravity settling. But, gravity settling alone failed to provide consistent enough pollutant removal at the desired levels of operation. In consequence, dewatering facility decant occasionally exceeded local pretreatment limits for lead of 0.7 mg/L. The City's goal is to consistently meet a 0.2 mg/L limit. In response, the City began plans for a second six-figure facility expansion project to provide additional gravity settling capacity.

Working in cooperation with the Oregon Department of Transportation (ODOT) and the Oregon Department of Environmental Quality (DEQ) under the auspices of the Federal Highway Administration (FHWA) funded ODOT Roadwaste Research Project, Portland also explored methods for achieving better removal of decant solids with the existing facility. Because Portland's stormwater Vactor® waste represents the worst case for stormwater residuals quality in Oregon, finding a best value solution to Portland's Vactor® waste decant pretreatment problem promised to be helpful to roadwaste management agencies elsewhere, as well.

Portland conducted chemical flocculation trials as one alternative, and trial results are documented in the Phase Two Report of the ODOT Roadwaste Research Project (Ghezzi, M., Collins, J., Moore, J., Bretsch, K., and Hunt, L., 2001). Electroflocculation, as demonstrated by Dennis Jurries, PE, of the Oregon DEQ using stormwater with suspended fines from construction site erosion (Jurries, 2000), was also considered. These methods were found practicable, but the projected treatment costs of about US\$0.38 per liter were deemed prohibitive.

Reasoning that only a marginal increase in decant quality was required, that some of the stormwater treatment value provided by plants in a constructed wetland might occur if a large enough planting could be propagated and maintained in the decant tank, that the potential benefits were high and the cost of failure was low, the author initiated a search for suitable aquatic plants.

Voluntary duckweed (*Lemna*) colonies had previously appeared in the tank, but were flushed through the system during rain events. Pennywort was selected for trial because it is free-floating, easily contained, a locally acceptable native, and available. Risks of escape were well considered. Because it propagates by budding, seed distribution by wind or animal life is not a risk.

## **Implementation**

A trial of phytoremediation was begun in May of 2001 by introducing a 19-liter starter bucket of the floating marsh pennywort plant material into the first cell of the decant tank (Figure 1.). *H. ranunculoides* is a native, free floating perennial found throughout the United States (PLANTS Database, 2002). The plant material was gleaned from an ornamental pond maintained on the grounds of the City's Columbia Boulevard Wastewater Treatment Plant.



**Figure 1** Photograph shows pennywort growing in the first cell of Portland's Vactor© waste decant tank. About three months after its initial introduction into the tank, the pennywort has formed a dense colony about 2.5 m square.

Plastic roll screening material with 1.3 cm openings and non-woven filter fabric of the kind used in erosion control were used to confine the plant material in the first cell of the tank.

The plant material thrived and filled out the cell by July of 2001 (Figure 2). So far, the plant material has proven hardy in this implementation. Just as in an ornamental planting, it pales and slows its growth during the winter months, but no substantial winter dieback has occurred. It also pales and slows its growth during the warmest sunny summer months, when decant tank flow is warmed and reduced by evaporation.



**Figure 2.** Photograph shows a dense matt of the vigorous pennywort completely covering the surface of the first cell of Portland's Vactor© waste decant tank in August, 2002.

To further test the technology and compensate for variables such as weather and changes in Vactor<sup>®</sup> cleaning program activity which couldn't be isolated in this trial, additional plant material was introduced into the second cell of the decant tank starting in the Spring of 2002. A full second year review could be conducted in June of 2003.

## Operation

No appreciable additional operating needs or costs were presented by the introduction of plant material into the decant treatment stream during the trial. Thinning of the plant colony may eventually be needed. Replacement may be required if the very rare extended hard freeze that can occur in Portland proves fatal. No additional nutrients or other treatments have been required for the health of the plants. As a public health measure, the tank is treated with Bt (*Bacillus thuringiensis*) to inhibit mosquito hatching at appropriate intervals during the warm season.

At about six month intervals, both cells of the tank are drained, and the mucky settled solids are cleaned from the bottom by Vactor<sup>®</sup> extraction. The cleanings removed from the tank are placed back onto the Vactor<sup>®</sup> dumping pad for dewatering, remediation and recycling.

*H. ranunculoides* plants are available locally in the Portland, Oregon area from commercial nurseries which supply native aquatic plants at about US\$1.00 per plant. The starting colony for one cell in this trial probably consisted of the equivalent of 100 commercial plants.

If thinning or removal of the plant material is required, testing to assess pollutant concentrations in the removed material should be performed. As with any phytoremediation project, disposal of plant materials should be guided by the findings of appropriate testing.

## Monitoring

Accurately measuring the fine, contaminated, negatively-charged colloidal soil particles found suspended in stormwater Vactor<sup>®</sup> waste decant proved by itself to be a challenge. The standard pretreatment screening test for total suspended solids (TSS) proved imperfect, because the filter used to capture solids was found to have a 25-micron pore size. A particle size study found that over 90% of solids in the decant were under 25 microns.

We considered turbidity (NTU) as an alternative indicator, and rejected it because it also reflects other factors which couldn't be controlled in this operational setting, such as color from dissolved substances and non-target particles of organic matter. In the end, we chose total lead (EPA 200.8) as our primary monitoring parameter. Lead is adsorbed preferentially to the fine solids (Collins, 1999); and lead is the contaminant of concern for protection of the City's wastewater processes by decant pretreatment.

The progress of the plant colony was observed and photo-documented. Samples representative of the decant discharges were tested for lead at routine intervals dictated by the City's pretreatment compliance monitoring program. Older and younger plant material was removed from the tank for close visual inspection.

## Discussion

### *Appropriate and Successful Plant*

A perennial native species, *H. ranunculoides* (Figure 3) requires no special substrate or media. While relatives of this plant have been identified as invasive pest species in Britain and elsewhere, *H. ranunculoides* is listed as endangered in Illinois. In the maritime Pacific Northwest, it is considered a desirable native species for ornamental propagation. It presents no obvious risk of escape in the setting under trial. In Portland's trial, it quickly covered the surface area of the tank. It thrived for most of the year, being somewhat discouraged in growth only during the warmest and coolest months. The test site near Portland Airport did not experience a hard freeze during the trial period, however.



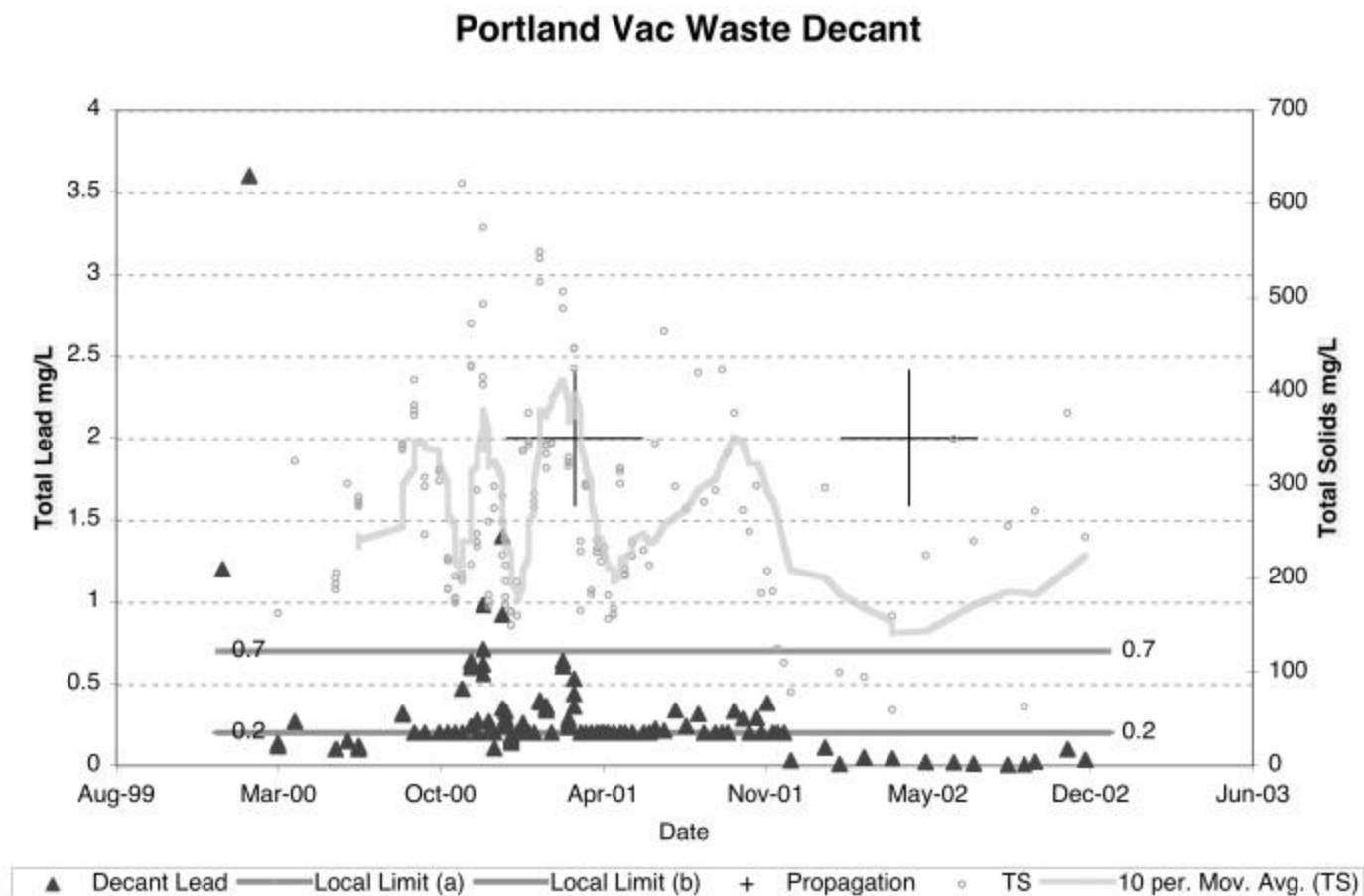
**Figure 3.** *H. ranunculoides* plant material shown against graph paper to illustrate form and scale. Depth of highly tangled root mass is about 10 cm. Height of mature stem and leaf is about 20 cm or more above root. Plant colonies form a dense floating matt.

Volunteer blooms of duckweed (Lemma) had appeared previously in the decant tank, but had been flushed out by rainfall events. *H. ranunculoides* is far more easily contained. In fact, it provides some containment for duckweed, which appeared as a minor voluntary overgrowth in the second summer. Based on visual observation as well as close handling of removed bucket samples, both the mass and immersed surface of the pennywort, with its heavy, tangled and tough, almost woody root system, broad leaves and long stems, dwarfed that of the duckweed in Portland's trial.

Plant material has not yet been sampled to determine the amount, if any, of metal hyper-accumulation. From an operational perspective, this testing will be critical to establish appropriate management of any plant material wasted from the process

### Apparently Successful Remediation

Operationally valuable improvement in decant lead results and visual observation appear to support the finding that *H. ranunculoides* is effective at remediating wastewater contaminated with lead bound to ultra-fine suspended solids in stormwater Vactor® waste decant. Previously absent flocculation and settling is observable in the tank and is the presumed method of remediation.



**Figure 4.** Graph illustrates Portland's Vactor® waste decant total lead and total solids results from January, 2000 to December, 2002, in relation to local wastewater pretreatment limits and the dates pennywort was introduced into the decant treatment regime, first in March 2001, and second in May 2002. A stable pattern of lower values has been coincident with the presence of the pennywort.

Decant monitoring for total lead and total solids shows (Figure 4.) that the presence of pennywort in the decant treatment stream has been coincident with an operationally significant and stable pattern of lower values. Prior to the introduction of the pennywort, exceedances of a 0.7 mg/L local limit were a source of concern. None have reoccurred since the introduction of the pennywort. No exceedances of the lower 0.2 mg/L limit have occurred since Fall of 2001.

## ***Minimal Cost***

Because the plant material for this trial was obtained as surplus from an ornamental planting, and the plant has proven both a vigorous grower, and to have no special operational needs in this implementation, the treatment cost observed in this trial is estimated at less than US \$0.01 per liter. Competing commercial technologies would run about 40 times that, based on Portland's previous trials.

## ***Unanswered Questions***

As a field trial, this project was successful enough. However, as a scientific endeavor, this project leaves many important questions unanswered.

Important variables such as changes in Vactor® cleaning program activity and rainfall could not be isolated in this full scale trial. How much remediation value is provided by plants alone in a controlled setting? Are the author's beliefs about the primary remediation mechanism verifiable in the lab? How much filtration is occurring? Fines may be adhering and then sloughing off the root surface; but, if so, this is not observable with the naked eye. Do the plant roots carry a slight positive charge? Will waste plant mass require special management? The author cannot say.

The data is good enough for operational purposes, but poor by scientific standards. The author has received expressions of interest from individuals in the academic community to take these investigations further, and hopes to see these questions answered in the future with their help. The author considers the field trial results presented in this paper preliminary but promising.

## ***Phytofloculation?***

The American Heritage Dictionary defines phytoremediation as, "the use of plants and trees to remove or neutralize contaminants, as in polluted soil or water (American Heritage Dictionary, 2003). In constructed wetlands and other biologically based wastewater treatment regimes, plants are widely recognized to provide treatment value via the natural phenomena of rhizofiltration, nutrient consumption and hyperaccumulation.

The EPA defines flocculation as a "process by which clumps of solids in water or sewage aggregate through biological or chemical action so they can be separated from water or sewage" (EPA, 2003). Based on field observation, the author believes that the plant material provided remediation by *flocculation* of the lead contaminated ultra-fine suspended solids in this trial. Although the exact mechanism of treatment has yet to be clearly established in the lab, the author proposes to call this natural phenomena *phytofloculation*.

## ***Thanks***

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